Sensor Fusion for Intelligent Process Control

PPG Industries

University of Utah

Sandia National Laboratories

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Project Team

- PPG Industries

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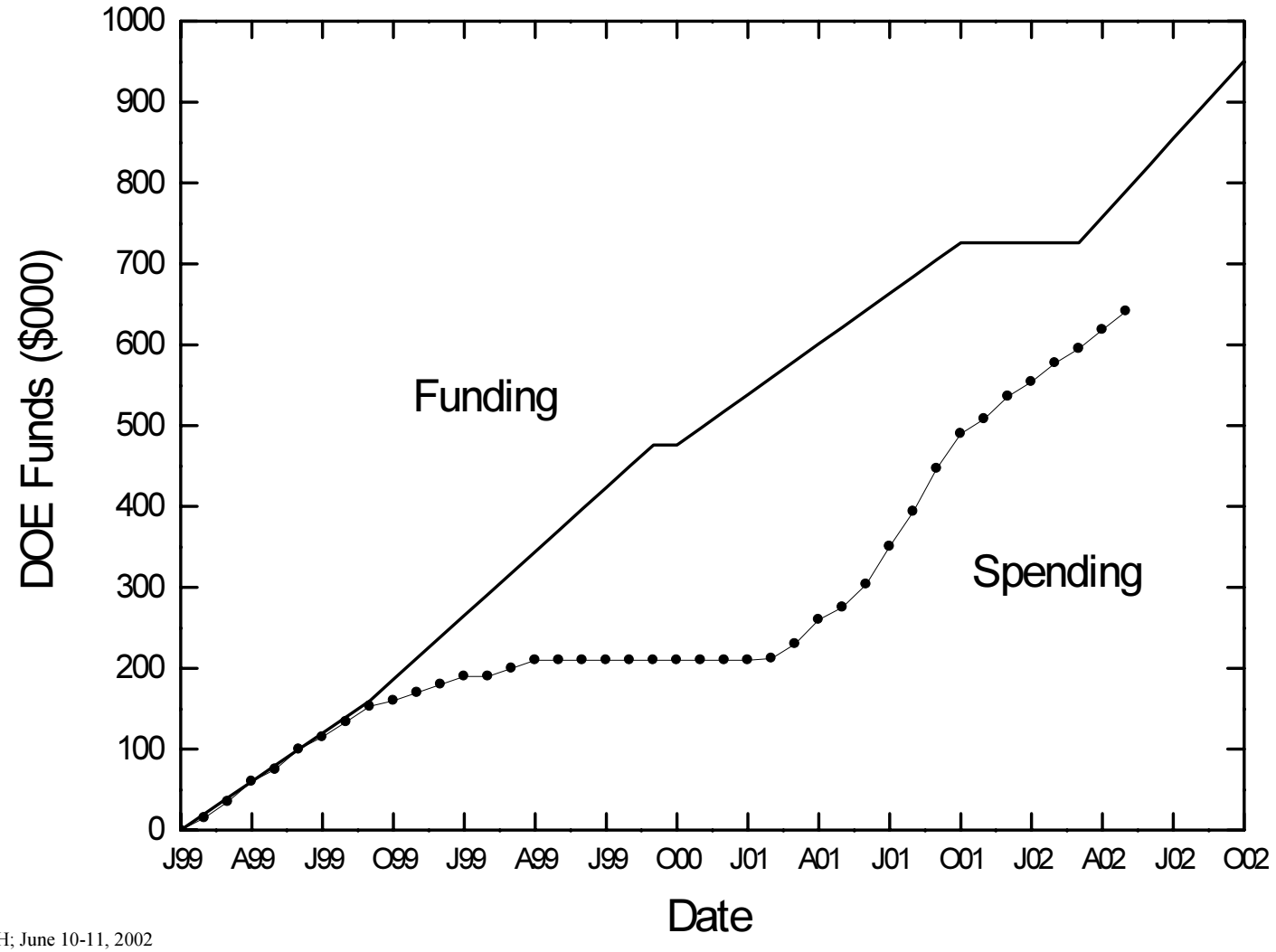
Intelligent Process Control: Goal

- Improve the combustion and emissions performance of air-natural-gas-fired regenerative glass melting furnace using hierarchical model-based combustion control to improve yields and fuel efficiency
  - Modeling and Simulation
  - Benchmark Furnace Performance
  - Sensors
  - Controls

Project Status

- Closing out project
  - Mid project cancellation
  - Afforded closeout funding to mitigate impact on PPG due to lost investment
- Modeling effort made tremendous progress and will continue until present work in complete
- Benchmark effort is complete and has presented a thorough report on furnace performance
- Sensor effort focused on air, flue gas, and oxygen measurements and has presented a thorough survey of existing technologies
- Control effort conducted a series of characterization tests and will modify the existing control structure

Funding and Spending



Benchmark and Sensor Findings

- Benchmark:
  - Established history of yield and output versus process parameters
  - Discovered a locations for a temperature sensor that correlates very well to several aspects of furnace performance and condition
- Sensor:
  - Measurement of air flow
    - Large fraction of the metered combustion air never reaches the furnace
  - Measurement of flue gas flow
    - Large fraction of the stack flow is contributed by inleakage
    - Furnace apparently lean, but actually rich
  - Identified most attractive technologies for sensing oxygen in the furnace and flues:
    - Platinum/zirconia probes-now
    - Diode laser absorption (Air Liquide/PSI S&C Project)-as soon as available

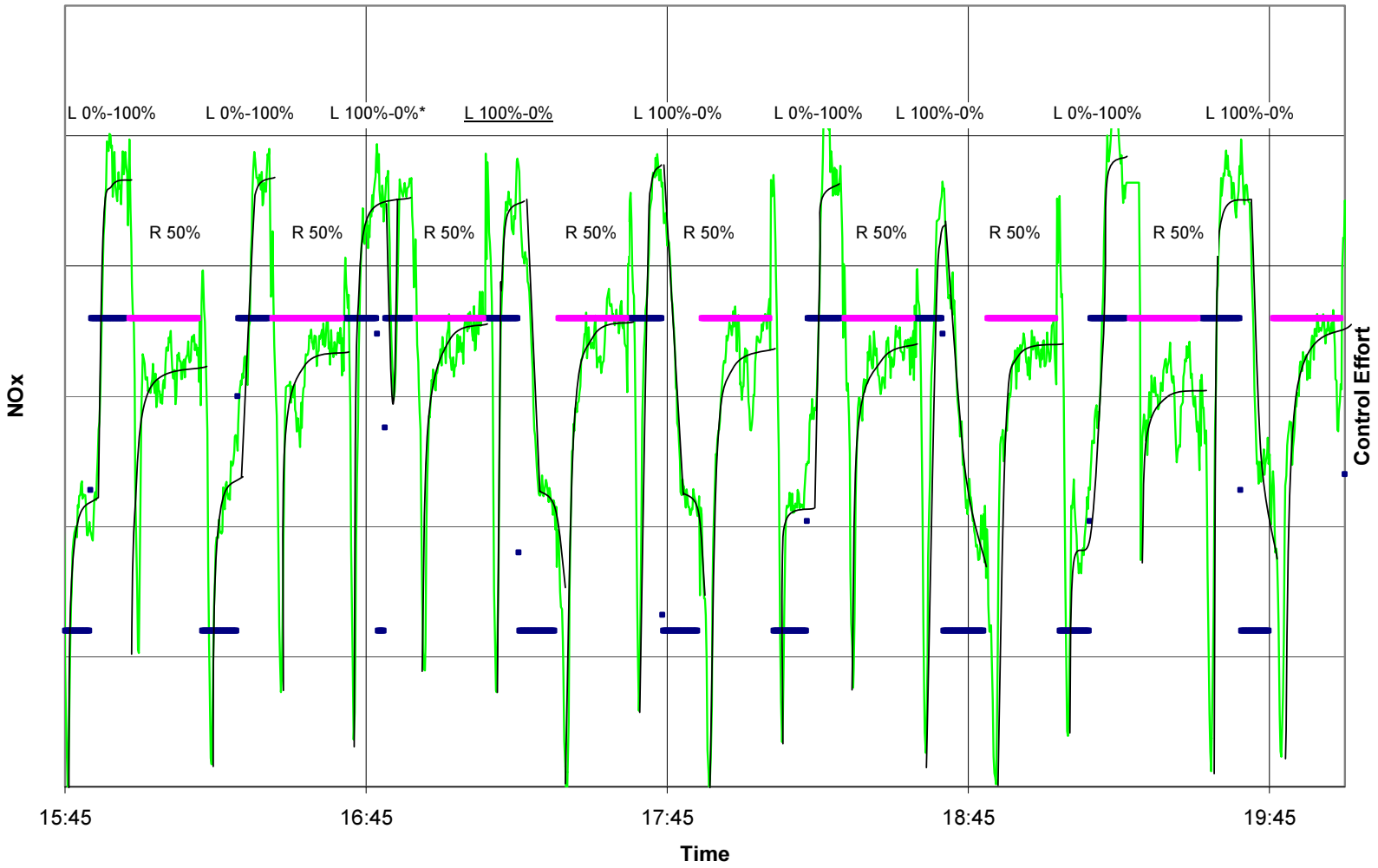
Control Work

- Crown temperature control: replaced a cascaded PID control loop with an Extended Horizon Self Tuning Control (EHSTC) loop
  - Reduced frequency of crown temperature fluctuation
  - Reduced operator intervention
- Control Infrastructure: implemented a batch control interface and quality control interface
  - Provided infrastructure for end-to-end process control
- NOx Control: performed series of experiments to characterize NOx production
  - Identified confounding process variables
  - Identified relationship between NOx and process variables

NOx Control Experiments

- Goal: Reduce and control NOx production while maintaining production levels and product quality
- Four days of intensive process manipulation
  - Shutting down control loops
    - Determine control loop interactions
  - Manipulating process variable
    - Whole furnace manipulation
    - Individual port manipulation
  - Identify relationship between process variable and process output
  - Identify process dynamics
  - Identify process sensitivity
- Presently performing extensive follow-up experiments on a more challenging glass product

NOx Control Experiments Excerpt



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Analysis of NOx Experiments

- Performed a statistically significant number of process manipulations to identify NOx Production:
  - Time Constant
  - Transport delays (from controls manipulation to measurement)
  - Gain: magnitude of NOx production to process control effort
  - Confirm NOx production conditions (furnace leak rates)
  - Identify NOx production confounding process interactions
  - Determined level of firing cycle hysteresis

Wrapping up the Control Work

- We will analyze the ongoing NOx production test results
- We will manipulate the NOx control loops to utilize the knowledge gained during this project
- We will detail all of our control related findings in a report

Project Conclusions

- This high risk project that PPG has taken on has produced some high payoffs for the community
  - High risk: loss of production, quality, and profits
  - High payoff: furnace control knowledge that will reduce pollution while increasing productions rates and maintaining quality and profit
- Afforded the National Laboratories and Universities the opportunity to provide help to US industry with a real problem with immediate benefit